Troubleshooting an Air Conditioning system

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Troubleshooting of an air conditioning system is a step by step procedure. I have found that a 4 step procedure is the best way to see how well a system is operating.

The 4 steps are:

1. **Volts and Amps**
2. **Evaporator Superheat**
3. **Condensing Subcooling**
4. **Temperature difference of coils**

Not one of these method alone can be used by itself to charge or troubleshoot an air conditioning system rather they must be used together to ensure efficiency and capacity.

Voltage and Amps

When working with voltages and Amps, one must consider the rated voltage and amp compared to the actual voltage and amp. Measure the starting amps along with the running amps of the compressor and all components of a system. When charging an air conditioner system the compressor amps changes due to the change in compression ratio. To find a compression ratio:

1. **Take the gauge pressure reading on both sides of the system and add 15 lb to each side. This makes absolute pressure.**
2. **Next divide the absolute high side pressure by the absolute suction pressure. This will equal compression ratio.**

When taking voltage and amp readings on a system, be aware of high and low voltages. On three phase equipment an imbalance in the voltage will give you an amperage imbalance. A good rule to consider is, for every 2% of voltage imbalance you will receive a 17% amp imbalance. Low voltage causes a high amp draw on systems. Good rules to use are:

1. **On a split voltage motor (208-230) the voltage should be within +10% or - 5%;**
2. **On a single voltage motor (208 or 230) the voltage should be within +- 10%.**

Not only is voltage very critical but the amp can tell us how hard a compressor is working and is a good indication of a charge. One cannot charge to amps only, but it still a good indication of the charge. A system run at full load when it is at full load conditions which is when the outside air is at 95ºF dry bulb and the inside air is at 80ºF dry bulb, 67ºF wet bulb that is about 50% relative humidity and at rated air flow.

So when one is reading the amp and voltage on an operating system always compare the operating amp to the nameplate amp and voltage.

Evaporator Superheat

Evaporator superheat is a calculation of the amount of liquid refrigerant going into the evaporator and the heat load of an air conditioner evaporator. An evaporator coil in an A/C system runs at a temperature of between about 34°F to about 44°F in most cases. A/C with a fixed orifice is charged to the superheat of the suction line leaving the evaporator 8ºF to 30ºF superheats (see chart).

The two most common metering devices used in air conditioning systems are the fixed orifice and thermostatic expansion valve. The thermostatic expansion in a refrigeration system is set at 8ºF to 12ºF superheat. In an air conditioning system different manufacture set at different points usually set between 10ºF to 14ºF +-2ºF. Each of these metering devices is charged differently. The thermostatic expansion valve will open and close with the superheat of the evaporator and the fixed orifice will never change in size by itself.

The superheat of a thermostatic expansion valve is normally set between 10ºF to 14ºF +-2ºF can vary with the design of a system. To measure superheat for a thermostatic expansion valve, the measurement must be obtained at the leaving refrigerant line of the evaporator, where the thermostatic expansion valve bulb is located.

An air conditioning system with a fixed orifice is charged to the superheat of the suction line leaving the evaporator. The superheat of a fixed orifice is normally set between 8º to 30º. I have found that each manufacturers superheat chart is slightly different and they different for different model numbers of the same brand of equipment. When there are changes in the efficiency rating of an air conditioning system the superheat can change. A fix orifice system has a critical charge. The smaller the system is the more critical is the charge of refrigerant. A fix orifice itself has no means to adjust the flow of refrigerant to maintain superheat. The only adjustment for superheat is the charge of refrigerant. There are two reasons that cause a change in superheat in fix orifice system:

1) The amount of refrigerant entering the evaporator and
2) The total heat of the air entering the evaporator.

Force and load set the superheat.

Force is the pressure of the high side, forcing the refrigerant into the fix orifice so it can be measured by the outside air temperature at the condenser. Load is the total heat of

the air entering the evaporator and can be measured by the wet bulb temperature. Wet bulb temperature is an indication of the total enthalpy of the air. When outside air temperature changes or the heat (enthalpy) of entering air to the evaporator change, the superheat changes. Superheat is the gas temperature above the saturated temperature. Superheat can be split into two types of heat:

1. **Superheat of the evaporators; and**
2. **Total superheat is entering the compressor.**

The evaporators superheat must be figured at the evaporator outlet not at the compressor inlet. Total superheat is figured at the compressor inlet and takes into accounts for the suction line loss or pressure drop.

To measure evaporator superheat

1. **Take a pressure reading of the suction line.**
2. **Convert pressure to temperature with a pressure temperature chart. If reading is obtained at the compressor, not at the evaporator leaving line, you may have to add a few pounds of pressure due to pressure drop in the suction line.**
3. **Take a temperature reading at the leaving suction line of the evaporator.**
4. **Subtract the saturated temperature from the leaving suction line temperature.**

The difference is the amount of heat the refrigerant gas has heated past saturated temperature.

This four-step procedure is known as the calculation of superheat. Manufacturers should be able to identify the amounts of superheat they have designed into a system. A low charge will give a high superheat and low amp draw. An overcharge will give a low superheat and high amp draw along with a higher compression ratio. To determine what superheat in a system should be, use the manufacture’s charging chart similar to the following chart.

Always check for proper evaporator air flow when charging a fix orifices superheat, be sure to use the charts that each manufacturer's can supplies for the system that is being charged.

Superheat for A/C with fixed Orifice R-22

Evaporator Inlet Air Temperature Fahrenheit Wet Bulb (enthalpy)

	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
Outside Air Temperature Dry bulb																	
60	7	11	13	17	18	20	24	26	28	30							
65		8	11	13	15	17	18	22	25	28	30						
70			8	11	12	14	16	18	22	25	28	30					
75				7	10	12	14	16	18	23	26	28	30				
80					6	8	12	14	16	18	23	27	28	30			
85						6	8	12	14	17	20	25	27	28	30		
90							6	9	12	15	18	22	25	27	28	30	
95								7	11	13	16	20	23	24	26	28	30
100								5	8	11	14	18	20	22	24	26	28
105									6	8	12	15	19	21	23	25	26
110									5	7	11	12	17	19	21	23	25
115										5	8	13	15	17	20	22	23

(Table3) (+- 2F°)

Condensing Subcooling

At saturation pressure-temperature point, the change of state becomes latent heat (invisible or hidden heat). Latent heat is a lack of rise or fall of temperature during a change of state (saturation). When the temperature does not rise or fall it is at saturation and the change of state process begins. Refrigerant continues to change state at one pressure-temperature. At saturation the only variable that can change a temperature is a pressure change. If a temperature change occurs a pressure change occurs. If a pressure change occurs a temperature change occurs.

At the change of state the refrigerant liquid and vapor are at the same temperature. This is defined as equilibrium contact. The temperatures of the liquid and vapors will stay the same until the temperature of the refrigerant starts to drop. Temperature of the refrigerant will start to drop once 98% to 99% of the refrigerant becomes a liquid. This is called subcooling. Subcooling in an air condition system is about 15ºF +- 10ºF. Subcooling is a temperature below saturated pressure temperature. Subcooling is a measurement of how much liquid is in the condenser. In air conditioning, it is important to measure subcooling because the longer the liquid stays in the condenser, the greater the sensible (measurable) heat loss. A TXV is charged to the subcooling of the refrigerant, check the superheat, but charge to the subcooling.

Low subcooling means that a condenser is almost empty. High subcooling means that a condenser is over field of liquid. Over charging a system with refrigerant increases pressure due to the liquid filling of a condenser and shows up as high subcooling. To move the refrigerant from condenser to the liquid line, it must be pushed down the liquid line to a metering device. If a pressure drop occurs in the liquid line and the refrigerant has no subcooling, the refrigerant will start to re-vaporize (change state from a liquid to a vapor creating bubbles, flash gas) before reaching the metering device.

An A/C with a Thermostatic Expansion Valve (TXV) is charged to the subcooling of the liquid line leaving the condenser because the superheat is fixed by the TXV. The superheat is specified by manufacturer and is normal between 10 to 14 degrees +- 2ºF in most residential air conditioning systems. Subcooling is the amount of liquid held back in the condenser. This allows the liquid to give up more heat, below saturated pressure-temperature. For every one degree of subcooling at the same condensing+ pressure, capacity will increase .5 percent. Increasing subcooling with an increase of discharge pressure and compression ratio, decrease capacity. Add 5 degrees of subcooling for

every 30 feet of liquid line lift to prevent the formation of bubbles, flash gas due to the pressure drop.

To measure subcooling:

1. **Take a pressure reading of the liquid line leaving the condenser.**
2. **Convert pressure to temperature with a pressure temperature chart.**
3. **Take a temperature reading at the leaving liquid line of the condenser.**
4. **Compare both, the saturated temperature and leaving liquid line temperature. Subtracting one from the other, the difference is the amount the refrigerant has cooled past saturated temperature.**

This four-step procedure is known as subcooling. Manufacturers should be able to identify the amounts of subcooling they have designed into a system. A low charge will give a low subcooling. An overcharge will give a high subcooling along with a high compression ratio. Do not worry about a few bubbles in the sight glass. Sight glasses will not always be clear with a full charge and may still be undercharged when the sight glass is clear. The zeotropes refrigerant group is known for this problem because of their fractionation. It is possible to never have a clear sight glass. To determine what the subcooling should be in a system use the manufacturer’s chart similar to the following.

Subcooling for A/C with TXV R-22

Outside Air Temperature DB	Evaporator Inlet Air Temperature Fahrenheit Wet Bulb 57	59	61	63	65	67	69	71	73
75	25	24	23	22	21	20	19	18	17
80	24	23	22	21	20	19	18	17	15
85	23	22	21	20	19	18	17	16	14
90	22	21	20	19	18	16	15	14	12
95	21	20	19	18	17	15	13	12	10
100	20	19	18	17	15	13	12	10	8
105	19	18	17	16	14	12	10	8	6
110	17	16	15	13	12	10	8	6	4
115	15	14	13	12	10	8	6	4	2

(Table 3) + --2 degrees

Temperature Difference in an A/C Evaporator

Temperature difference of an evaporator coil will vary with the total heat of the air entering the evaporator and the load on the condenser. This temperature will vary from 10º F to 30º F depending on total heat of the air entering the evaporator. With air flow at normal operating conditions the temperature difference should be 16ºF to 22ºF.

The temperature of air decreases progressively as the air passes through an evaporator coil. The drop in air temperature is greatest across the first row of the coil and diminishes as the air passes across each succeeding row. The fact that the temperature

difference between the air and the refrigerant is greatest across the first row, and becomes less and less as the temperature of the air is reduced in passing across each succeeding row. The temperature difference is least across the last row of the coil.

External factors affect coil performance. Principal among these are the circulation, velocity, and distribution of air in the cooled space and over the coil. These factors are closely related and in many cases is dependent one on the other.

Heat from the product or conditioned space is carried to the evaporator by air circulation. When air circulation is inadequate, heat is not carried from the product or conditioned space to the evaporator at a rate sufficient to allow the evaporator to perform at peak efficiency or capacity. It is important also that the circulation of air is evenly distributed in all parts of the cooled space and over the coil. Poor distribution of the air circulating can result in uneven temperatures and dead spots in the air conditioned space. Uneven distribution of air over the coil surface causes some parts of the surface to function less efficiently than other and lowers evaporator capacity and efficiency.

When air velocity is low, the air passing over the coil stays in contact with the coil surface longer. More heat is removed and is cooled with a greater range. Thus, the temperature difference increases, the refrigerant temperature decreases, resulting in a loss of capacity and efficiency because the rate of heat transfer is lowered. As air velocity increases, a greater quantity of air is brought into contact with the evaporator

coil. Consequently, the temperature difference decreases, the refrigerant temperature increases, resulting in a gain of capacity and efficiency because the rate of heat transfer is increased. Therefore air volume change across the coil will increase or decrease the refrigerant temperature. That increases or decreases the efficiency and capacity of a system. Increasing the heat by increasing the airflow or increasing the evaporating coil size by 10% will give a decrease of water removed from the air by 2% to 4%, but there will be a 4% to 8% capacity increase. This will result in a sensible heat increase in the system from a 72% to 74% and a latent heat decrease from 28% to 26%. An increase of the refrigerant temperature of 1ºF will increase compressor efficiency by 1% to 2%.

The reason for the increase in heat and the increase in refrigeration temperature is due to the increasing size and/or airflow of the overall coil. Over size an evaporating coil or increase airflow, decreases the water removing latent heat capacity of a coil.

Decreasing heat by a decrease of airflow or an evaporating coil size by 10% will result in a 2% to 4% increase of water removed from the air, and will cause a 4% to 8% capacity decrease. The capacity decrease results in a decrease of sensible heat from 72% to 70% thereby causing a latent heat increases of 28% to 30%. A decrease of the refrigerant temperature of 1ºF will decrease compressor efficiency by 1% to 2%.

The decrease compression efficiency is caused by the decrease in heat, and the refrigeration temperature that is due to the decreasing size and/or airflow of the overall coil. Under sizing an evaporating coil or a decrease of refrigerant temperature, increases the water removing capacity of a coil.

Lowering the refrigeration below airs dew point temperature in an existing evaporator coil will remove more water from the air or will increase water-removing capacity. This can be done by lowering the airflow or downsizing the coil but not increasing the coil size. The coolest refrigerant temperature is 34 degrees (no ice on the coil).

It is possible to check the airflow of an evaporator coil by knowing the air entering dry bulb and well bulb temperature. This chart is for an air condition system that is design at 400 CFM per ton, which removes 6.667 enthalpy (BTU per pound of air) and that is 72% sensible 28% latent load. For higher efficiency systems that have more air flow add 2ºF to the leaving air temperature.

Indoor Entering Air T° Dry Bulb	Indoor Entering Air Temperature Wet Bulb																									
	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
68	47	48	50	50	51	51	52	52	53	54	54	55	56	57												
70	49	50	51	51	52	52	53	53	54	55	55	56	57	58	59	60										
72	50	51	51	52	52	53	54	54	55	56	57	57	58	59	60	61	62	63								
74	51	52	52	53	53	54	55	55	56	57	58	58	59	60	61	62	63	64	65	66						
76	52	53	53	54	54	55	55	56	57	57	58	59	60	61	62	63	64	65	66	67	68	69				
78	53	54	54	55	55	56	56	57	57	58	59	60	61	62	63	64	65	66	67	68	69	70	70	71		
80	54	55	55	56	56	57	57	58	58	59	60	61	62	63	64	65	66	67	68	69	70	70	71	72	72	73
82	55	56	56	57	57	58	58	59	59	60	61	62	63	64	65	66	67	68	69	70	70	71	72	72	73	74
84	56	57	57	58	58	59	59	60	61	62	63	63	64	65	66	67	68	69	70	71	71	72	72	73	74	75
86	57	58	58	59	59	60	60	61	62	63	64	65	66	67	68	69	70	70	71	72	72	73	73	74	75	76
88	58	59	59	60	60	61	61	62	63	64	65	66	67	68	69	70	71	71	72	72	73	74	74	75	76	77

Indoor Leaving Evaporator Coil Air Temperature Dry Bulb

1. **Measure the dry bulb temperature with a digital thermometer of the air entering the evaporator.**
2. **Measure the wet bulb (water vaporization temperature) temperature with a digital sling psychrometer of the air entering the evaporator. Do not let the sock dry out on a sling psychrometer or the reading will be the same as the dry bulb temperature. The wet bulb temperature is read only when the temperature stops dropping; this may take time, 10 to 15 minutes.**
3. **Find the measured indoor entering dry bulb temperature on the left side of the table and the wet bulb temperature on top line.**
4. **Where the lines cross, that should be the leaving dry bulb air temperature.**
5. **Compare the Table's leaving air temperature with the leaving air of the coil.**
6. **If the measured leaving air-dry bulb temperature is 3F° or lower than the proper leaving air temperature, increase the evaporator fan speed.**
7. **If the measured leaving air-dry bulb temperature is 3F° or higher than the proper leaving air temperature, decrease the evaporator fan speed.**

Temperature Difference in an A/C Condenser

Temperature difference in a condenser will depend on the efficiency and load of the system. Efficiency of the condenser coil can change the temperature across the coil from about 12ºF to 30ºF. Manufacturers should be able to identify the amounts of temperature difference of a condenser they have designed into a system. A low charge will give a low temperature difference. An overcharge can give a high temperature difference along with a high compression ratio.

Temperature difference across the condenser coil can be affected by dirt on a coil. Most coil run between 100ºF to 120ºF of saturation the change of state. Dirt particles of only 50 microns can start affecting the temperature of the refrigerant condensing. Air

flow and recycled air affect the temperature of the refrigerant and the temperature difference of the coil. Condenser coils need to be clean when they get dirty. If you see dirty it needs to be cleaned. Use water or a caustic base cleaner. When a chemical is used on the coil all the chemical must be removed so the coil is not damage. So manufactures Trane and Carrier recommend against using acid or caustic cleaners detergents only.

Condensing coil need to be placed where they are not in the hottest location. For every 10ºF above 95ºF a system will lose 6% of efficiency.

Conditions	Suction Pressure	High side Pressure	Evaporator Superheat	Condensing Subcooling	Evaporator ΔT°	Amp
			TXV/Fixed	TVX/Fixed		
High Charge	High	High	Normal/Low	High	Lower	High
Low Charge	Low	Low	High	Low	Low	Low
Over Feeding metering	High	Low	Low	Low	Low	Normal to Down
Under feeding metering	Low	Low	High	Low	Low	Low
Weak Vales	High	Low	Low	Low	Low	Down to Low
Restricted Liquid Line	Low	Up then Low	High	Up then to Pressure T°	Low	Low
Restricted Evap Air Flow	Low	Low	Down/low	High	High	Low
Restricted Cond Air Flow	High	High	Down/Down	Low	Low	High
Low Load						
Evaporator	Low	Low	Down/Low	High	High	Low
Condenser	Low	Low	Down/Low	High	Up	Low
High Load						
Evaporator	High	High	High	Low	Low	High
Condenser	High	High	Up/down	low	Low	High
Noncondensible	Up	High	Down/high	high	low	high

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